ESSAY REVIEWS

Science and Civilization in China: Volume 4, Part 2: Mechanical Engineering. By Joseph Needham. Pp. iv + 759. 158 plates. London: Cambridge University Press, 1965. £9 10*s*.

"Having regard to the span of time and to the population concerned", wrote A. N. Whitehead, "China forms the largest volume of civilization which the world has seen." We would expect to find, therefore, that the Chinese had achieved some degree of technical mastery; for although the social variables permit options—slavery, for example—it is clear that civilization presupposes a minimum level of technical attainment: and the Chinese do not appear to have depended much on slave labour.

In this latest volume of this notable series, Dr. Needham has set out to evaluate the Chinese contribution to "mechanical engineering". This amounts to an impressive series of inventions, some of which seem to have spread from China all over the civilized world. It is, however, difficult for the Western reader to appreciate sympathetically the lives and works of Chinese inventors for these were often interpreted for us by third parties: writers and artists who were not technicians themselves. Thus, either because the artists had little feeling for the machines they illustrated or because of a peculiar artistic convention, it is often difficult to tell from the illustrations in this book just how the machines were supposed to have worked. Does this perhaps reflect the bureaucratic nature of Chinese society? For Dr. Needham tells us that the inventor and technician rarely rose to high rank in the all-important bureaucracy.

Some confirmation of this hypothesis is supplied by the fact that many of the most elegant Chinese inventions seem to have had little practical economic value. The ingenious "south pointing" carriage, the (pedal driven) paddle-wheel boat and the kite—surely the most profitless of all inventions?—suggest that delight in ingenuity was often sufficient motive for Chinese inventors. In contrast, Western mechanical invention during the industrial revolution was utilitarian and marked by a strong cost/profit consciousness. This was not the attitude in China where, according to Dr. Needham, the mercantile classes and, one assumes, their ideologies, were treated with contempt. Was Chinese mechanical invention therefore the technics of a society dominated by the ideas and values of a literary educated bureaucracy? Certainly the pinnacles of Chinese invention—the astronomical clocks with their subtle escapement mechanisms—were primarily of administrative value and only indirectly of commercial significance. Lastly, we must not forget that when the Jesuits reached China at the end of the sixteenth century, the Chinese appear to have forgotten their earlier inventions and this suggests that, lacking autonomous economic justification, Chinese inventiveness was ultimately stifled by bureaucracy.

Thus Dr. Needham's fascinating account also provides many clues to aid our speculations on why the inventive impulse eventually flagged. But on some of his points Dr. Needham will not carry all his readers with him. His laudable desire that we should do justice to Chinese achievements leads him to stress Chinese priority on every possible occasion: a cumulatively self-defeating procedure. The propagation of inventions was always a slow and inefficient process and the reader who recalls how frequently independent and simultaneous inventions occurred in the eighteenth and nineteenth centuries will probably feel that Dr. Needham underrates the likelihood of such occurrences in China and the West in earlier epochs. Again, Dr. Needham seems too indulgent in appraising particular inventions. Thus the story of the eight cornmills worked by one bullock may, or may not, confirm Chinese priority in the art of driving

several machines from one shaft, or motive agent; but the sceptical reader must wonder whether the Chinese had also bred a bullock with eight times the endurance of normal animals. More controversial is the ascription to the Chinese of a fundamental role in the invention of the steam engine. This cannot be sustained. Selecting one or two important components of the first steam engines and tracing them back to what are claimed as their origins in very different arts in a different continent is a doubtful historical method. In any case, the important point about the steam engine is that here was a prime mover which competed successfully with established agents—animal muscle, wind and water —and which worked day in, day out, reliably, powerfully, cheaply. The credit for this belongs to Papin, Savery, Newcomen and Watt and the magnitude of their achievement was such that it is not profitable—and hardly just—to seek antecedents before the seventeenth century. Similarly, the turbine, invented and named by Burdin in 1824, was an advanced machine designed in the light of the then established theories of *vis viva* and *work*. With respect to Dr. Needham and to the historians he quotes it is very difficult to accept that it was invented, or even foreshadowed, in medieval times.

In short Dr. Needham has written a stimulating and scholarly work which will cause discussion and, one hopes, further research. His commitment to China is fair and unconcealed and while one must disagree with some of his conclusions, his work will inevitably diminish parochialism among historians of technology. The Chinese have long had a reputation among Europeans for ingenuity (fireworks and puzzles!) and also for being irritatingly superior in their attitude towards Western technology and science. They have had their own considerable achievements—efficient horse-harnesses, wheelbarrows, water wheels, etc.—as Dr. Needham makes clear. One possible implication then is that these people, confronted by mature Western technology, were expressing no more than the simple truth when they asserted that the West had little to teach them. A commercial civilization with a technology based substantially on mining and one of whose key inventions in mechanical engineering—the machine tool—seems to have been hardly known in China (only simple lathes are mentioned in this book) could perhaps have little to say to an ancient feudal and agrarian society guided by a literary-minded bureaucracy. But for some answers to these and other questions provoked by this book we shall have to wait for Dr. Needham's later publications.

D. S. L. Cardwell

Twentieth-century Cosmology

The Measure of the Universe. A History of Modern Cosmology. By J. D. North. Pp. xxviii + 436. London: Clarendon Press. Oxford University Press, 1965. 70*s*.

Cosmologie du XXe Siècle. By Jacques Merleau-Ponty. Pp. 533. Paris: Gallimard, 1965. 30 *F*.

From the Greeks to the invention of the telescope, cosmology (in the sense of physical science) was practically identical with astronomy. It then became moribund, and revived in a new form just after the first world war. These books are concerned only with the revival.

The contrast between the old and the new cosmology exhibits in the clearest way what I believe will later be recognized as the chief characteristic of the current period in physical science—namely, the transformation of mathematics from the role of servant to that of master of science. The aim of the old cos-